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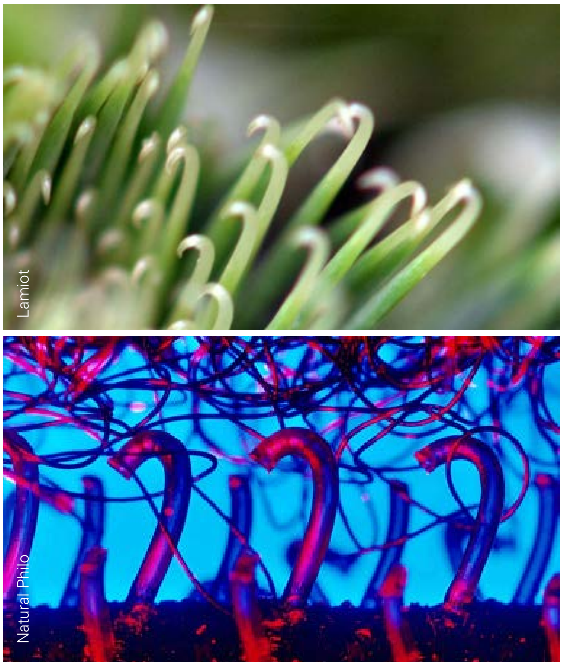
Biomimicry

Materials that imitate life

Key words
biomimetics
evolution
natural selection
technology

Biomimicry means imitating life. Why should we do this? All living things have developed methods of overcoming problems and they have had many generations to do so. Humans, by comparison, have only been solving problems for a few generations.

The science of biomimetics is defined as 'the study and development of synthetic systems that mimic the formation, structure or function of biologically produced substances, materials and processes'. An everyday example is the development of the hook and loop tape called Velcro. In 1941, coming back from a hunting trip in the Alps, the engineer George de Mestral noticed that the fruits of the cockle burr were very difficult to remove from his clothing and his dog's coat. Inspired by nature, he developed materials of hooks and loops that worked the same way as the plant fruits. The plant evolved the hooks as a means of dispersing fruits containing seeds over a wide area. They are especially good at attaching to mammalian fur.



The hooks of burdock inspired the invention of Velcro

Kingfisher train

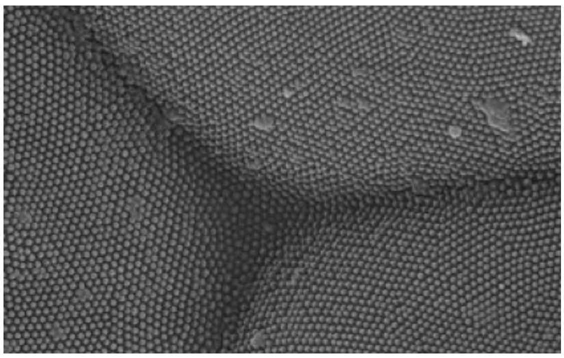
The first Japanese bullet trains only travelled at 210 km/h because they made too much noise and created a sonic boom when leaving tunnels that could be heard by local residents 400 m away. One of the engineers, Eiji Nakatsu, happened to be a keen birdwatcher and wondered how a kingfisher could dive so fast from air into water with ease. The shape of the kingfisher beak was investigated and found to be optimum: a rotational parabolic body or a squashed diamond shape.

The shape was used to design the nose of the next generation of bullet trains. Along with other modifications the result was less noise, more efficient power consumption and speeds up to 300 km/h.

The beak of the kingfisher gave engineers insight into high-speed train design.

Non-reflective eyes

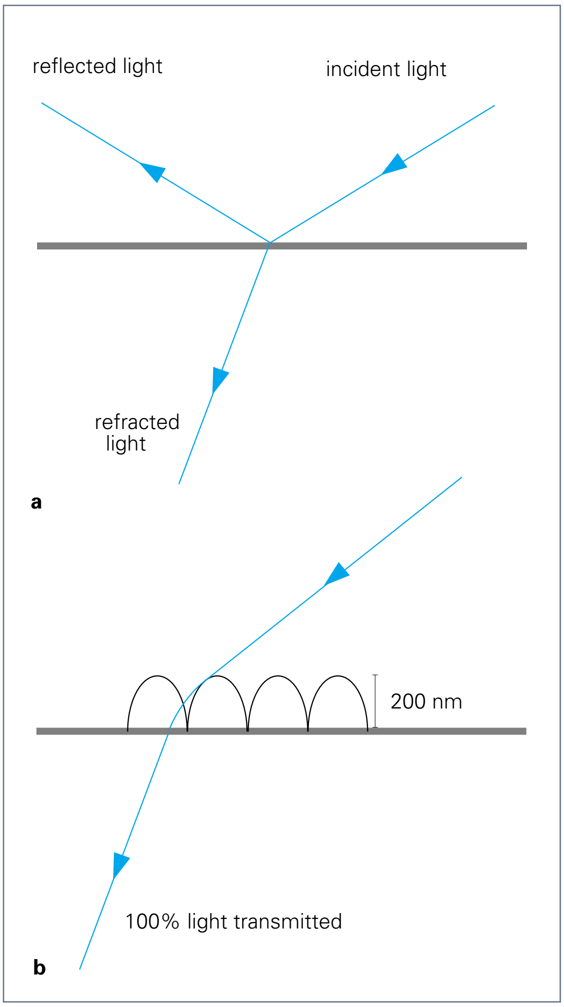
The compound eye of an insect is built of thousands of identical structural units called ommatidia. These are packed together to form a large round compound eye. Every ommatidium has an outer surface made of a substance called chitin. In some species of moth the outer surface is not smooth when viewed under an electron microscope but rather composed of very large numbers of small bumps. These bumps, called nano-nipples, reduce reflection to allow as much light as possible to enter the insect's compound eye. This adaption allows moths to fly in low light conditions.



A scanning electron micrograph of nano-nipples on the surface of a moth's eye

How does this work? When light passes from one transparent medium to another, a fraction of it is reflected. This is because of the change in refractive index n – that's why we see reflections in shop windows (for glass $n = 1.4$, for air $n = 1.00$). The refractive index of chitin is $n = 1.57$, so an even greater fraction of light is reflected.

The nano-nipple surface means that the refractive index changes gradually from 1.00 to 1.57 and so very little light is reflected.



*Reflection and refraction: **a** The eye of the Monarch butterfly has a smooth surface so 5% of light is reflected. **b** The Mourning Cloak butterfly has nano-nipples on its eye surface so reflection is greatly reduced.*

So how did the surface of insect eyes develop nano-nipples? Within a population of any species there will be natural variations of structure. This means that the surface of some eyes will not be as smooth as others. If there is a selection pressure that favours eyes that reflect a little less light (due to the rough surface) then these individuals have a better chance for passing on the trait for the rough surface. If this selection pressure is maintained for generations then the eye surface becomes rough as chitin is laid down with nano-nipples. This is the process of natural selection.

Monarch butterflies have a smooth eye surface. As they fly during the day there is no advantage to preventing light reflection. As energy and more organic molecules would be needed to make the nano-nipples these structures do not develop unless there is a selection pressure.

Anti-reflection surfaces have been developed to improve readability in sunlight. They reflect as little as 1% of incident light. Solar panels can be made with a moth eye surface coating to capture more light energy. So the evolution of a biological structure can be mimicked to improve the efficiency of sustainable energy supplies.

Slithering snakes

How do snakes slither so easily? There is no obvious difference in the structure of snake scales on their upper and lower surfaces. However the scales of the lower surface produce less friction. This allows the snake to move across rough surfaces without damaging its skin.

A California kingsnake

Under an electron microscope the scales of the California kingsnake have a coating of lipid molecules. These are arranged in rows and columns only on the lower scales. The snake may be moving on the tips of these molecules and this layer may have self healing properties. More research is being done to find out whether the lipids just keep the scales from drying out or they are the source of the reduction of friction. Low friction lubricants modelled on this lipid layer may reduce wear on moving parts in all types of mechanical devices.

Biology branching out

There are many other examples of large and small-scale biological solutions to problems that have already been identified. Organisms have developed solutions over millions of years by the mechanism of natural selection, design by evolution. The study of biomimetics is a new branch of biology that has the promise of providing better solutions to existing problems.

John Stacey is a retired teacher based in East Sussex.